MYCOLOGIA

VOL. I NOVEMBER, 1909 No. 6

CULTURES OF UREDINEAE IN 1908[1]

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The present article forms the ninth of a series of reports[2] by the author upon the culture of plant rusts, covering the years from 1899 to the close of 1908. The grass and cedar rusts have been especially prominent in the years' work. Very considerable advance has been made in segregating the subepidermal rusts on grasses that have generally passed under the name of *Puccinia rubigo-vera,* and some particularly notable results were achieved with forms of *Gymnosporangium,* partly in finding unexpected aecial connections for well-known telial species, and partly in segregating species heretofore confused under European names.

This year for the first time since the series of cultures was begun, the Indiana Experiment Station at Purdue University, where all the study has been conducted, assumed the full expense of the work. Heretofore the extra assistance needed during the chief cultural period of about six weeks has been paid for in part or wholly from outside sources. This year the cultural work was made a part of an extended investigation of cereal and other rusts to be conducted by the station, and the expenses met from the Adams fund, derived from the general government. The more definite and certain financial support has made it possible to better systematize and conduct the work.

As in the previous year some collecting trips made expressly

[1] Read before the Botanical Society of America at the Baltimore meeting, December 31, 1908.

[2] See Bot. Gaz. **29**: 268–276, **35**: 10–23; Jour. Myc. **8**: 51–56, **10**: 8–21, **11**: 50–67, **12**: 11–27, **13**: 189–205, and **14**: 7–26.

[MYCOLOGIA for September, 1909 (1: 177–224), was issued 11 Sep. 1909.]

to secure culture material proved helpful to an extent far beyond the proportional amount of time consumed. The earliest one took Mr. F. D. Kern and the writer to Mammoth Cave in Kentucky. It was specifically undertaken to discover a telial form to accompany the aecia known to occur on *Porteranthus stipulatus* (*Gillenia stipulacea*). A careful microscopic examination made during the winter of 1907–8 of the aecia on this host, which were collected by Rev. C. H. Demetrio in 1884 at Perryville, Mo., and distributed as No. 3323 in Rabenhorst-Winter, Fungi europaei, under the name of *Roestelia lacerata,* which it much resembles, showed that the fungus was undoubtedly a true *Roestelia,* although the host is an herb belonging to the rose family. As this is the only known instance of the aecial stage of a *Gymnosporangium* occurring on any host outside of the woody plants of the apple family, the detection of the telial form appeared to be a matter of more than usual interest. The original collection was apparently the only one known, until a search was made through the phanerogamic herbaria in a number of places, and a few pycnia were detected on a collection of the host at the New York Botanical Garden, which was made at Mammoth Cave, in June, 1870, by Dr. T. F. Allen. Upon writing to Rev. Demetrio it was learned that the locality of the original collection has been turned into cultivated fields, quite destroying the chances of making a second collection in the original habitat. It was known to the writer that the estate of several thousand acres about the Mammoth Cave has been in litigation for a number of years, and that few changes have taken place in the long period during which the cave has been an object of world-wide interest to tourists. After considering these facts it was decided to visit the vicinity of the cave, hoping to detect material from which cultures could be made. Two days were spent at the cave. The most careful search on the first day was in vain, although the host was found as tender shoots only a few inches high, and also an abundance of red cedar trees. The second day afforded better success, and considerable material of what appeared to be a new form of *Gymnosporangium* was discovered on the trunks of small cedars growing near plants of *Porteranthus,* although pycnia and aecia could not be expected owing to the earliness of the season. Sub-

sequent cultures confirmed the inferences from field observation, and abundantly justified the method pursued in this case in tracing the life history of a little or imperfectly known rust.

The next important excursion to points outside of the state of Indiana was made by my associate, Mr. F. D. Kern, the writer's ill health preventing further active participation in securing material for the work of the season. Mr. Kern reached Denver, Colo., on May 16, and spent five days collecting material and making field observations chiefly along the foot hills from Boulder on the north to Trinidad on the south. During this time he had the invaluable assistance of Mr. E. Bethel, the able mycologist of Denver, who supplied important information about suitable localities to visit, and for part of the time himself went along to help in every way possible. The results fully justified the time and outlay, especially in the way of knowledge regarding the numerous and intricate forms of cedar rusts. The telia of the true *Roestelia cornuta* were collected on this trip for the first time in America. The telia of the true *R. penicillata,* little known in America, were also taken, but owing to misfortune in manipulation did not lead to successful cultures.

On his return journey from Colorado Mr. Kern made a detour to Racine, Wis., where as the guest of Dr. J. J. Davis he visited in an automobile the Wind Lake locality, made familiar to mycologists by Dr. Davis' numerous collections and observations. Here material was obtained of the juniper rust, believed to be associated with the *cornuta*-like aecia on *Aronia.* It had been sent by Dr. Davis for cultures in previous years, but had not been brought to germination. This is the type locality for the species, to which Mr. Kern has given the name *Gymnosporangium Davisii.*[3]

At our request Mr. H. S. Jackson, of Newark, Del., made some fruitful collecting tours for observations on the Atlantic coast rusts. A two days' trip to Seaford and Lewes, Del., was made the middle of November, 1907, and again to the same places the latter part of April following. The duplicate trip was especially designed to secure observations on the early appearance of aecia in the immediate vicinity where telial culture material had pre-

[3] Bull. Torrey Club 35: 507. 1908.

viously been taken. Mr. Jackson proved a keen observer, detecting a new species on *Carex comosa* with its probable aecia on *Smilax,* and both aecia and telia of *Puccinia subnitens,* the first collection of it made on the Atlantic coast, beside much other serviceable information. He also made a trip to Newfield, N. J., on May 15, and secured telial material of cedar rusts from the region made familiar by the late Mr. J. B. Ellis.

The season's cultural work was, with the exception of some cedar rust cultures made by Mr. Kern, in the hands of Mr. A. G. Johnson, a graduate of the South Dakota Agricultural College, and a former special student of Washington University, St. Louis, who was recommended for the position by Dr. E. W. Olive. He was diligent and enthusiastic in the work, and made successful cultures of the largest number of species secured in any one season during the ten years that the cultural work has been in progress.

In this series of studies the amplitude of the results is largely dependent upon the kindly assistance of correspondents in providing culture material and in communicating field observations. Acknowledgments are due this year to Mr. E. Bethel, Denver, Colo., who is far in the lead with more than fifty collections of culture material, and to Messrs. H. S. Jackson, Newark, Del., J. M. Bates, Red Cloud, Neb., R. E. Stone, Auburn, Ala., A. O. Garrett, Salt Lake City, Utah, Elam Bartholomew, Stockton, Kans., E. W. Olive, Brookings, S. D., E. W. D. Holway, Minneapolis, Minn., H. J. Webber, Ithaca, N. Y., T. D. A. Cockerell, Boulder, Colo., J. L. Sheldon, Morgantown, W. Va., A. B. Seymour, Cambridge, Mass., G. P. Clinton, New Haven, Conn., P. B. Kennedy, Reno, Nev., Guy West Wilson, Fayette, Iowa, George L. Potter, Lima, Ind., J. J. Davis, Racine, Wis., A. R. Sweetser, Eugene, Ore., C. W. Edgerton, Donald Reddick and C. J. Humphrey, all three of Ithaca, N. Y., W. A. Kellerman, at the time in Guatemala, C. G. Lloyd, Zacatecas, Mex., and J. Dearness, London, Ont. This enumeration gives scanty credit where in many cases special trips, often of many miles, were undertaken at our request to secure at a definite time either dry material or live hosts, or to make observations, which would further a particular inquiry. Mention should also be made of

the assistance rendered by Dr. Wm. Trelease, of the Missouri Botanical Garden, St. Louis, Mo., who sent plants of *Porteranthus stipulatus* on which the new cedar rust was sown. The writer extends his warmest thanks to the above individuals and to others who have assisted in the year's investigations.

During the present season 204 collections of material with resting spores and 26 collections with active spores were employed, from which 565 drop cultures were made to test the germinating condition of the spores. Out of the 204 collections with resting spores 99 could not be brought to germination although seemingly in perfect condition leaving 105 collections of available material. These 105 collections with resting spores and 26 with active spores belonged to about 60 species of rusts. Altogether 321 sowings were made, employing for the purpose 114 species of hosts, these being grown in pots, so that the work of attempted infection could be conducted wholly in the greenhouse.

The results of this work are given in the following paragraphs, and are divided into negative results, positive results with species whose life cycles have already been ascertained by the writer or other investigators, and positive results with species whose life cycles are now first placed on record.

NEGATIVE RESULTS:—Quite a number of collections gave good germination of the spores, but no infections were secured. The following may be recorded to serve for reference in future studies:

1. PUCCINIA on *Carex pennsylvanica* L., collected at Red Cloud, Neb., by Rev. J. M. Bates, was sown on *Arabis Holboellii,* with no infection. Similar material was sown in previous seasons on thirty-eight other species of hosts.[4]

2. PUCCINIA VULPINOIDIS Diet. & Holw., on *Carex vulpinoidea* Michx., collected at Newark, Del., by Mr. H. S. Jackson, was sown on *Viola cucullata, Chelone glabra, Aster paniculatus, Ambrosia trifida, Cacalia reniformis, Laciniaria punctata, Rudbeckia laciniata* and *Senecio obovatus.* A similar collection made at London, Ontario, by Mr. J. Dearness, was sown on *Callirrhoe involucrata* and *Rudbeckia laciniata.* Still a third collection made

[4] See Jour. Myc. 10: 10. 1904; 11: 51. 1905; 12: 12. 1906; 13: 191. 1907; and 14: 9. 1908.

by the writer at Lima, Ind., was sown on *Napaea dioica, Ambrosia trifida, Aster Drummondii, Boltonia asteroides, Cacalia reniformis, Laciniaria spicata, Rudbeckia laciniata* and *Senecio obovatus.* None of the trials resulted in infection.

3. PUCCINIA on *Carex gravida* Bailey, sent by Rev. J. M. Bates from Red Cloud, Neb., was sown on *Abronia umbellata, Vernonia arkansana,* and twice on *Artemisia dracunculoides,* with no infection. Similar material from the same region has been sown in previous years upon forty-four other species of hosts with negative results.[5]

4. PUCCINIA on *Carex* sp., sent by Mr. C. W. Edgerton from Ithaca, N. Y., was sown on *Iris versicolor* twice, with no infection. This was the culmination of a series of observations to ascertain the telial form belonging to aecia on *Iris,* which had been noticed for a number of seasons in one locality near the town of Ithaca. Four collections taken from the close vicinity of the rusted *Iris* were sent for trial in 1907, two of which grew well on *Aster paniculatus,* but not on *Iris,* while the other two failed to germinate. All four of these collections agreed morphologically with *Puccinia Caricis-Asteris* Arth. In continuation of the search for the true alternate form for the *Iris* rust, Mr. Edgerton sent this season from practically the same spot a rust on an undetermined *Carex,* having morphological characters quite unlike those of *P. Caricis-Asteris,* and approximating, if not identical with, *P. quadriporula* Arth. As no positive results were obtained from this material the identity of the alternate form of the aecial rust on *Iris* still remains in doubt.

5. PUCCINIA DULICHII Syd., on *Dulichium arundinaceum* (L.) Britt., collected at Seaford, Del., by Mr. H. S. Jackson, was sown on *Decodon verticillatus, Smilax hispida, Lysimachia quadrifolia* and *Senecio obovatus,* with no infection.

6. PUCCINIA EMACULATA Schw., on *Panicum capillare* L., collected at Fayette, Iowa, by Prof. Guy West Wilson, was sown on *Macrocalyx Nyctelea, Hydrophyllum virginicum, Amorpha fruticosa,* and *Napaea dioica,* with no infection. Similar material was sown in previous seasons on twenty-three other species of hosts.[6]

[5] See Jour. Myc. 10: 10. 1904; 11: 51. 1905; 12: 12. 1906; 13: 191. 1907; and 14: 10. 1908.

7. PUCCINIA SCHEDONNARDI K. & S., on *Schedonnardus paniculatus* (Nutt.) Trel., collected at Boulder, Colo., by Mr. E. Bethel, was sown on *Thalictrum polygamum* and *Grindelia squarrosa,* with no infection. Like material was sown in previous seasons on eighteen other species of hosts.[7]

8. PUCCINIA ELLISIANA Thüm., on *Andropogon scoparius* Michx., collected at Newark, Del., by Mr. H. S. Jackson, was sown on *Actaea alba, Ambrosia trifida, Anemone virginiana, Dirca palustris, Hydrophyllum virginicum, Ipomoea pandurata, Isopyrum biternatum, Iva frutescens, Pentstemon hirsutus, Phacelia bipinnatifida, Psoralea Onobrychis* and *Verbena urticifolia,* with no infection. Similar material from Colorado was sown the previous year on ten other species of hosts.[8]

9. PUCCINIA VEXANS Farl., on *Atheropogon curtipendulus* (Michx.) Fourn. (*Bouteloua racemosa* Lag.), collected at Stockton, Kans., by Mr. E. Bartholomew, was sown on *Apocynum cannabinum, Caulophyllum thalictroides, Dalea laxiflora, Delphinium tricorne, Hydrophyllum virginicum, Napaea dioica, Polemonium reptans, Symphoricarpos racemosus, Smilax hispida* and *Thalictrum dioicum,* with no infection. This is the first time that an attempt at infection with teliospores has been made, although the amphispores were successfully grown on the same grass host last year.

10. PUCCINIA POCULIFORMIS (Jacq.) Wettst., on *Phleum pratense* L., collected at Sayre, N. Y., by Prof. H. J. Webber, was sown May 1 on *Berberis vulgaris.* Another collection of the rust from Ithaca, N. Y., sent by Mr. Donald Reddick, was sown May 6 on five plants of *Berberis vulgaris,* and once more on May 13. As no infection showed after the usual interval, the same material was again sown May 22 on three plants of the barberry, and for three successive nights after sowing the inoculated plants were placed in an ice box at a temperature of 10° C. in order to insure more favorable conditions for the penetration of the germ tubes into the tissues of the host. Again on May 28

[6] See Bot. Gaz. 35: 12. 1903; Jour. Myc. 8: 52. 1902; 10: 10. 1904; 12: 12. 1906; 13: 192. 1907; and 14: 11. 1908.

[7] See Bot. Gaz. 35: 11. 1903; Jour. Myc. 13: 192. 1907; and 14: 11. 1908.

[8] See Jour. Myc. 14: 10. 1908.

the same material was sown on *Mahonia Aquifolium.* In each instance the ready germination of the teliospores was established by a drop culture within twenty-four hours preceding the time of sowing, as is done for all the culture work reported in this and preceding years. In no case was an infection secured.

The reasons for believing that this rust should be referred to *Puccinia poculiformis,* in spite of the failure to produce aecia on *Berberis* or *Mahonia,* have been briefly stated by Mr. Frank D. Kern,[9] who has also recorded the history of the appearance of the rust in North America, and it is only necessary that the writer affirm his agreement with Mr. Kern's conclusions.

11. PUCCINIA ASTERIS Duby, on *Aster arenarioides* D. C. Eaton, sent from Salt Lake City, Utah, by Mr. A. O. Garrett, was sown on *Aster Drummondii, A. paniculatus, A. multiflorus* and *Callistephus hortensis,* with no infection. This adds little to the solution of the problem whether the leptopuccinial rust on various species of *Aster* in the different sections of the country are all referable to one species or not.

12. UROMYCES GRAMINICOLA Burr., on *Panicum virgatum* L., collected at Stockton, Kans., by Mr. E. Bartholomew, was sown on *Althaea rosea, Apios tuberosa, Cacalia reniformis, Callirrhoe involucrata, Decodon verticillatus, Hibiscus militaris, Napaea dioica* and *Viola cucullata,* with no infection.

13. UROMYCES ANDROPOGONIS Tracy, on *Andropogon glomeratus* (Walt.) B.S.P., collected at Lewes, Del., by Mr. H. S. Jackson, was sown on *Viola cucullata,* while a similar collection on the same species of host, sent from Auburn, Ala., by Mr. R. E. Stone, was sown twice on *Viola cucullata,* and also on *Comandra umbellata, Dasystoma flava* and *Pentstemon hirsutus,* all with no infection. From the field observations reported by Dr. John L. Sheldon it seems almost certain that the aecia of this rust occur upon *Viola,* and the repeated failure of the cultures may have been due to the maturity of the *Viola* leaves on which the sowings were made.

SUCCESSFUL CULTURES SUPPLEMENTING PREVIOUS WORK:— The following species of rusts were successfully grown, and the facts supplement what have been obtained from previous cultures

[9] Kern. The Rust of Timothy. Torreya 9: 3–5. 1909.

in this series or have been recorded by other American or European investigators. In a number of cases the previous definite knowledge of the species has been materially extended.

1. PUCCINIA KUHNIAE Schw., on *Kuhnia Hitchcockii* A. Nelson, collected at Marshall, Colo., Feb. 22, 1908, by Mr. E. Bethel, was sown May 14, on *Kuhnia eupatorioides.* Numerous pycnia appeared May 24, duly followed by abundant uredinia June 4, and telia June 29. This result confirms the work in 1905,[10] and shows that in all probability all collections of rust on this genus of hosts are referable to the one autoecious species.

2. PUCCINIA PECKII (DeT.) Kellerm., on *Carex stipata* Muhl., collected Oct. 23, 1907, at Lima., Ind., by Mr. George L. Potter, was sown on *Onagra biennis* (L.) Scop., April 28, and gave pycnia May 9 and aecia May 18, both in great abundance.[11]

3. PUCCINIA SAMBUCI (Schw.) Arth., on *Carex lurida* Wahl., collected at Lagrange, Ind., by the writer, was sown on *Sambucus canadensis* L. May 15, and gave a great abundance of pycnia May 23, and aecia June 1.[12]

4. PUCCINIA CARICIS-SOLIDAGINIS Arth., on *Carex sparganioides* Muhl., collected at Lima, Ind., and again at Lagrange, Ind., both by the writer, was sown from the first named locality April 11 on *Aster Drummondii,* giving no infection and again May 4 on *Solidago canadensis* L., giving abundant infection with pycnia showing May 12, and aecia May 19. From the second locality sowings were made April 15 on *Aster paniculatus* and *Solidago canadensis,* giving no infection on the first host, but abundant infection on the second, showing pycnia April 23, and aecia May 5.[13] This result duplicates that obtained in 1905.

5. PUCCINIA ELEOCHARIDIS Arth., on *Eleocharis palustris* (L.) R. & S., obtained at Lima, Ind., by the writer, was sown on *Eupatorium perfoliatum* L., May 13, giving rise to pycnia May 22,

[10] Jour. Myc. 12: 23. 1906.

[11] For previous cultures see Bot. Gaz. 35: 13. 1903; Jour. Myc. 8: 55. 1902; 11: 58. 1905; 12: 15. 1906; and 13: 195. 1907.

[12] For previous cultures see Bot. Gaz. 35: 14. 1903; Jour. Myc. 8: 55. 1902; 12: 14. 1906; and 13: 195. 1907.

[13] For previous cultures see Bot. Gaz. 35: 21. 1903; and Jour. Myc. 12: 15. 1906.

and aecia June 2, both in abundance, thus confirming the work of 1905 and 1906.[14]

6. PUCCINIA ANGUSTATA Peck, on what was probably *Scirpus cyperinus* (L.) Kunth, the plant showing only leaves but growing with plants with fruit, gathered at Spirit Lake, Iowa, by the writer, was sown April 13 on *Lycopus communis* Bickn., giving rise to pycnia April 25, and aecia May 3, both in abundance. It was sown again May 2 on *Lycopus americanus* Muhl., giving rise to an equal abundance of pycnia May 11, and of aecia May 19, the interval between the appearance of pycnia and aecia being exactly the same as in the first culture.[15] The result is interesting in connection with an observation made by the writer while on an excursion in the vicinity of Ithaca, N. Y., June 30, 1906. An abundance of rusted *Lycopus communis* was gathered, with uredinia appearing on close-by plants of *Scirpus cyperinus,* while plants of *L. americanus* and *S. atrovirens* growing intermixed were both quite free from rust. The field observation seemed to indicate a biological difference between the rust occurring on the two species of *Scirpus* and the associated *Lycopus,* and with a view to experimental tests healthy plants of *L. communis* from the Ithaca locality were sent to the greenhouse at Lafayette, the species not occurring in Indiana or Iowa. These were the plants used in the present cultures. The results seem to warrant the tentative conclusion that P. *angustata* within some geographical areas is inclined to form races confined to certain hosts, while in other geographical areas the differentiation into races does not occur, a condition that appears to arise in other species as well, *e. g., Puccinia subnitens* Diet.

7. PUCCINIA SUBNITENS Diet., on *Distichlis spicata* (L.) Greene, was available in two collections from Delaware, two from Nebraska and two from Nevada, representing three areas approximately on the fortieth parallel of latitude, but twelve hundred miles between stations in longitude. The Delaware station is on the Atlantic sea coast; the Nebraska station is midway of the continent on the great plains, with the Allegheny range of

[14] For previous cultures see Jour. Myc. 12: 23. 1906; and 13: 197. 1907.

[15] For previous cultures see Bot. Gaz. 29: 273. 1900; Jour. Myc. 8: 53. 1902; 11: 58. 1905; 13: 196. 1907; and 14: 14. 1908.

mountains intervening; while the Nevada station is within two hundred miles of the Pacific coast, and between it and the Nebraska station intervenes the great expanse of the Rocky Mountains.

The chief question demanding solution was whether this remarkable heteroecious rust, which forms aecia on many species of hosts belonging to the families Cruciferae, Chenopodiaceae and Capparidaceae, has developed biological differences, as previous work had indicated.[16] In all thirty sowings were made. A few of these proved failures because the plants used as hosts did not grow well. The important results may be given without recording all the data.

The collections from the Atlantic coast, the first reported from east of the Mississippi river, were made by Mr. H. S. Jackson, at Lewes, Del., Nov. 16, 1907. Aecia were taken the following spring in close proximity on seedling plants, which were fruited in Lafayette, and ascertained to be *Atriplex hastata.* Ten sowings were made from these collections, using *Chenopodium album, C. hybridum, Iva frutescens* on which in the same locality aecia had also been found the following spring, and *Decodon verticillatus,* with infection only on *Chenopodium album,* which was abundant.

The mid-west collections were made, one by Rev. J. M. Bates, at Red Cloud, Neb., and the other by Mr. R. E. Stone, at Lincoln, Neb. These were sown on *Chenopodium album, C. hybridum, Sarcobatus vermiculatus, Monolepis Nuttalliana* and *Cardamine bulbosa,* with infection only on the first-named species.

The far-west collections were made by Prof. P. B. Kennedy, at Reno, Nev. They were sown on *Chenopodium album, Atriplex hastata* and *Sarcobatus vermiculatus,* at three different dates, fourteen sowings being made. Abundant infection resulted for all the hosts; nine plants giving equally vigorous results, the other five not thriving well.

These results taken with those of 1906 and 1907 show that no marked biological differences exist. The only indication of restricted adaptation is the failure to infect *Sarcobatus* from Nevada with teliospores from Nebraska, although, as predicted

[16] Jour. Myc. 13: 197. 1907, and 14: 15. 1908.

two years ago,[17] there is no difficulty in producing infection on *Sarcobatus* from Nevada with teliospores from the same region.[18]

8. PUCCINIA SEYMOURIANA Arth., on *Spartina cynosuroides* Willd., collected at Lima, Ind., by Mr. George L. Potter, was sown May 28 on *Cephalanthus occidentalis* L., giving rise to numerous pycnia June 6, and aecia June 15.[19]

9. PUCCINIA FRAXINATA (Schw.) Arth., collected at Lewes, Del., by Mr. H. S. Jackson, on *Spartina polystachya* Willd., was sown April 25 on *Adelia ligustrina, Ligustrum vulgare* and *Fraxinus lanceolata,* with infection only on the last-named species. Again on May 2 it was sown on *F. lanceolata,* giving very abundant pycnia May 13, and aecia June 2.

Another collection from the same locality, but on *Spartina stricta* Roth, was sown on *Smilax hispida* and *Fraxinus lanceolata,* with infection on the last species only.

Collections of aecia, which morphologically are identical with those of *Fraxinus,* have been made on *Ligustrum vulgare* in New York, and *Adelia segregata* in Florida. In 1904 and 1905 attempts were made to grow aecia on plants of these genera, but without success. As the telia came from the western plains, it was thought that telia from the Atlantic sea coast might show less restricted adaptation. So far we are unable to detect any difference in behavior between the rust of the salt marshes of the coast and that of the prairies of the west. It yet remains to try telia from the south along the gulf coast.[20]

10. PUCCINIA TOMIPARA Trel., on *Bromus purgans* L., collected at Scotia, Neb., by Rev. J. M. Bates, was sown on *Clematis virginiana* L. and *Thalictrum dioicum* L., May 29, giving pycnia on the first-named host only June 7, and aecia June 16, both in abundance.[21]

11. PUCCINIA ASPERIFOLII (Pers.) Wettst., on *Secale cereale* L., collected by Mr. A. G. Johnson at Lafayette, Ind., July 21,

[17] Jour. Myc. 13: 198. 1907.

[18] For previous cultures see Bot. Gaz. 35: 19. 1903; Jour. Myc. 11: 54. 1905; 12: 16. 1906; 13: 197. 1907; and 14: 15. 1908.

[19] For previous cultures see Jour. Myc. 12: 24. 1906.

[20] For previous cultures see Bot. Gaz. 29: 275. 1900; Jour. Myc. 11: 57. 1905; 12: 16. 1906; and 14: 14. 1908.

[21] For previous cultures see Jour. Myc. 11: 62. 1905; and 13: 197. 1907.

1908, was sown July 22, on *Lycopsis arvensis* L. On July 31 a few pycnia appeared, but owing to the imperfect growth of the leaf no aecia followed.

This rust has usually gone under the collective name of *P. rubigo-vera* (DC.) Wint., which has been applied to most subepidermal grass rusts not having strongly marked morphological characters. The similar leaf-rust of wheat is clearly a distinct species, judging from the failure of European investigators to make it infect *Lycopsis,* from some morphological differences, and from its different period for germination. Teliospores of the leaf-rust from both wheat and rye were tested in the laboratory at the same time by means of drop cultures, and while the rye rust grew readily, the wheat rust showed no germination.

This unequivocal, although scanty result, the first culture of the kind to be made with American material, sets at rest any doubt regarding the identity of the American and foreign leaf-rust on rye. The writer is indebted to the kindness of Dr. P. Magnus, of Berlin, Germany, and Dr. H. O. Juel, of Upsala, Sweden, for seeds of *Lycopsis* from which plants were grown for the culture work.

12. UROMYCES SCIRPI (Cast.) Burr., on *Scirpus fluviatilis* (Torr.) A. Gray, collected by the writer at Spirit Lake, Iowa, was sown on *Cicuta maculata* April 6, and gave rise to pycnia April 14, and aecia April 23, both in abundance.

13. UROMYCES HOUSTONIATUS (Schw.) Sheldon. In the spring of 1906 Dr. J. L. Sheldon observed a rust appearing on plants of *Sisyrinchium gramineum* Curtis (S. *graminoides* Bickn.), growing in contact with plants of *Houstonia caerulea* bearing *Aecidium houstoniatum* Schw. The rust on *Sisyrinchium* proved to be *Uromyces Murrillii* Ricker, until then only once collected, at the type locality in Maine. Dr. Sheldon has since made further studies in the field, and also convincing inoculations,[23] and at the same time supplied ample material for repeating his results. The methods used for other species, however, have not proved available for this one, whose teliospores do not enter a resting condition, but germinate in the sorus as soon as mature. It is the only

[22] For previous cultures see Jour. Myc. 13: 199. 1907; and 14: 17. 1908.
[23] Torreya 6: 249. 1906; and 9: 54. 1909.

heteroecious rust known to the writer, having all spore forms and yet leptopuccineous. Plants of *Sisyrinchium* bearing the rust, sent by Dr. Sheldon in 1906, flourished well in the greenhouse, but the rust gradually disappeared during the following winter. The experience was repeated in 1907. In both cases by March or April the rust had died out and did not again appear, although the plants produced fresh leaves and flourished throughout the winter months and the whole year.

Living plants of *Houstonia caerulea* bearing aecia, sent by Dr. Sheldon from Morgantown, W. Va., May 3, were potted intermixed with plants of *Sisyrinchium gramineum*. On June 8 a few uredinia were observed, but did not multiply. On May 18 similar plants were sent by Mr. H. S. Jackson from Newark, Del. These were put into small pots, and on May 23 arranged over plants of *Sisyrinchium* under a belljar, where they remained three days. On June 7 a great abundance of uredinia was observed, and on July 22 telia also in abundance. As both urediniospores and teliospores are pale and inconspicuous, they doubtless appeared earlier than the record shows.

14. GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE Schw., on *Juniperus virginiana* L., was collected by Mr. F. D. Kern and the writer at Mammoth Cave, Ky., in two rather unusual forms. One form had very large galls, very irregular and much divided. The other had very small galls, with one to three telia each, the extruded part of the telia being noticeably fusiform. Both of these forms appeared so different from the forms usually collected farther north, that it seemed possible they might be specifically distinct.

The large form was sown April 13 on *Malus Malus* (L.) Britt., *M. coronaria* (L.) Mill. and *Crataegus punctata* Jacq. On *M. Malus* pycnia appeared April 23, but the infection was so pronounced that the leaves were distorted and injured to an extent that precluded the formation of aecia, the leaves gradually dropping until September 26, when two, the only ones still remaining, were removed for the herbarium. On *M. coronaria* abundant pycnia appeared April 21, followed duly by aecia of characteristic appearance. The *Crataegus* remained free from infection.

The small form was sown April 13 on *Malus coronaria* and

Crataegus punctata, giving a few pycnia on the first, not noticed until May 4, and abundant pycnia on the last, showing April 21. Both hosts matured characteristic aecia by the latter part of June.[24]

15. GYMNOSPORANGIUM GLOBOSUM Farl., on *Juniperus virginiana* L., collected by Mr. A. B. Seymour at Manchester, Mass., was sown April 29 on *Malus Malus,* producing no infection, and on *Crataegus Pringlei* Sarg. (seedling from tree determined by Mr. W. W. Eggleston), giving abundant pycnia, and followed by equally abundant aecia. Another collection made by Mr. F. D. Kern and the writer at Mammoth Cave, Ky., was sown April 13, on *Crataegus* sp., giving pycnia April 25, but nothing further, due to the death of the host.[25]

16. GYMNOSPORANGIUM CLAVIPES C. & P., on *Juniperus virginiana* L., collected at Mammoth Cave, Ky., by Mr. F. D. Kern and the writer, was sown on two plants of *Crataegus* sp., April 13, and gave pycnia on April 25, followed by aecia by the middle of June. A sowing two days later on *Aronia nigra* gave no infection.

Another collection on the same host, made by Dr. G. P. Clinton at New Haven, Conn., was sown May 2 on *Amelanchier erecta* with no infection, and on *Crataegus* sp., giving a few pycnia, but the early maturity of the leaves checked further development.[26]

17. GYMNOSPORANGIUM CLAVARIAEFORME (Jacq.) DC., on *Juniperus Sibirica* Burgsd., collected by Mr. E. Bethel at Eldorado Springs, Colo., was sown April 28 on the leaves, petioles and stems of *Amelanchier erecta* Blanch., giving pycnia May 5, and aecia May 23, both in great abundance.[27]

18. GYMNOSPORANGIUM NELSONI Arth., on *Juniperus scopulorum* Sarg., collected by Mr. E. Bethel at Eldorado Springs, Colo., was sown May 2 on *Amelanchier erecta* and *Sorbus americana,* both showing abundance of pycnia May 10. On the first host no further development took place, as the plant was not vig-

[24] For previous cultures see Jour. Myc. 12: 13. 1906; 13: 200. 1907; and 14: 17. 1908.

[25] For previous cultures see Jour. Myc. 13: 200. 1907; 14: 18. 1908.

[26] For previous cultures see Jour. Myc. 14: 18. 1908.

[27] For previous cultures see Jour. Myc. 14: 19. 1908.

orous. On the second host abundant and characteristic aecia were formed.[28]

19. GYMNOSPORANGIUM BETHELI Kern, on *Juniperus scopulorum,* collected by Mr. E. Bethel at Eldorado Springs, Colo., was sown May 11, on *Pyrus communis,* with no infection, and on *Sorbus americana,* and *Crataegus* sp., both giving numerous pycnia, on the former host showing May 19, and on the latter not seen until May 31, although probably appearing earlier. The pycnia in both cases were followed by an abundance of characteristic aecia, well formed by July 7.[29]

20. GYMNOSPORANGIUM BOTRYAPITES (Schw.) Kern, on *Chamaecyparis thyoides* (L.) B.S.P., collected by Mr. H. S. Jackson at Newfield, N. J., was sown on *Amelanchier intermedia* Spach, May 18, giving an abundance of pycnia May 28. Although galls followed the pycnia, no aecia were formed owing to the early maturity of the leaves. This is the *Gym. biseptatum* Ellis. The rather extended synonomy is given by Kern.[30] Inconclusive cultures of this species were made by Dr. W. G. Farlow in 1877 and 1883. In 1886 Dr. Roland Thaxter[31] made cultures, and raised both pycnia and aecia, repeating his work at a later date.

21. GYMNOSPORANGIUM CORNUTUM (Pers.) nom. nov. Telia on the branches of *Juniperus Sibirica* Burgsd. were collected May 19, 1908, by Mr. F. D. Kern and Mr. E. Bethel, at Palmer Lake, Colo., and sown May 23 on *Sorbus americana,* giving an abundance of pycnia June 1, followed by numerous aecia. A second sowing was made on another plant of the same host May 25, with equally successful results, the pycnia showing June 5. In both cases the aecia were mature by August 10. A sowing May 25 on *Malus Malus* gave no infection.

Although the horn-like aecia of this species are common and often collected, this is the first time that the telia have been found in America. The telia occur on the bark of the small branches, and not at all or only rarely on the leaves. In Europe cultures of this species were made by Oersted, of Denmark, in 1866, and an account with excellent illustrations of both aecia and telia was

[28] For previous cultures see Jour. Myc. 13: 203. 1907; and 14: 18. 1908.

[29] For previous cultures see Jour. Myc. 14: 23. 1908.

[30] Bull. Torrey Club 35: 506. 1908.

[31] Proc. Am. Acad. 22: 263. 1887.

published the same year.[32] Cultures have also been made since, but most investigators in the discussion of their results have confused this with other species.

The form which has been most persistently confused in the telial stage with the present species is what in Europe has been called *G. tremelloides* Hartig, which has much larger and otherwise different telia on the bark of the larger branches of the same species of juniper, but whose aecia are the true *Roestelia penicillata,* and although occurring on *Sorbus,* are easily distinguished by being fimbriate instead of horn-like. Mr. Kern[33] has recently shown from partly circumstantial evidence that this species is the *Tremella juniperina* L., and should be called *G. juniperinum* (L.) Mart. This disposition of the name, *G. juniperinum,* appears to leave no available name under *Gymnosporangium* for the present species, and a new combination is therefore necessary. The earliest specific name is that given by Persoon to the aecial form in 1791, *Aecidium cornutum,* the first species listed under the newly established genus *Aecidium.*

The other form included by European investigators with the present species has very small telia on the leaves of the same juniper, and horn-like aecia on *Aronia.* This is discussed in the following paragraphs under the name *G. Davisii* Kern.

22. GYMNOSPORANGIUM DAVISII Kern. It is with more than usual satisfaction that I report the successful culture of this rust, as it completes a knowledge of the life cycle of a trio of species known to some extent in both Europe and America for many decades, but much confused and misunderstood. The telia occur on the leaves of *Juniperus Sibirica,* and have been sent in previous years by Dr. J. J. Davis, from Wind Lake near Racine, Wis., but could not be made to germinate. A collection made in the same locality on May 24, 1908, by Dr. J. J. Davis and Mr. F. D. Kern, was sown May 25 on *Aronia nigra, Amelanchier erecta* and *Sorbus americana,* with infection only on the *Aronia,* which showed pycnia June 12, and well matured aecia Sept. 17. Another sowing was made May 25 on *Aronia nigra,* producing a few pycnia

[32] Overs. Danske Vid. Selsk. Forh. 1866: 185–196. pl. 3, 4, with full abstract in Bull. Soc. Roy. Dan. Sci. 1866: 15–16.

[33] Science 27: 931. 1908.

June 15, but did not further develop owing to weakness of the host.

The aecia of this species have the same horn-like appearance as those of *G. cornutum,* already discussed, and the two are usually included under the same name. The only culture known to the writer, showing that the form on *Sorbus* and the similar one on *Aronia* are distinct, was made by Dr. Ed. Fischer [34] of Bern, Switzerland, and published in November, 1907. On May 29 of that year he made a sowing of teliospores from *Juniperus communis* on *Sorbus Aria, S. torminalis, S. hybrida, S. Aucuparia, Amelanchier Botryapium* and *Aronia rotundifolia* (*Amelanchier vulgaris*), and obtained an infection only on *Aronia.* He concluded from this result that the form on *Aronia* is distinct from that on *Sorbus,* but made no suggestion regarding the nomenclature. Mr. Kern,[35] however, finds diagnostic characters to separate the forms in both aecia and telia, and has supplied a name. The cultures by Dr. Fischer were not known to the writer until long after the above studies had been concluded.

23. MELAMPSORA MEDUSAE Thüm., on *Populus tremuloides* Michx., collected at Boulder, Colo., by Mr. E. Bethel, was sown April 7 on *Ribes rubrum, R. Cynosbati* and *Larix laricina.* The only infection was on the *Larix,* showing pycnia April 14, and aecia April 21.[36] When the sowing was made, it was supposed that the rust in hand was *Melampsora albertensis* Arth.; but after the result was obtained a careful inspection of the remaining material of the collection brought to light the fact that while the leaves were conspicuously covered with that rust, they also bore some sori of the more common species, and it is believed that the infection came from the latter, as recorded above.

SUCCESSFUL CULTURES REPORTED NOW FOR THE FIRST TIME:—

The following species have never been cultivated, in America or elsewhere, so far as the writer knows. Much credit for the ample results is due to the mycologists who have coöperated in the work by making invaluable observations in the field and supplying suit-

[34] Archiv Sci. Phys. et Nat. 24: —. Nov. 1907.

[35] Bull. Torrey Club 35: 507. 1908.

[36] For previous cultures see Jour. Myc. 10: 13. 1904; 11: 52. 1905; and 12: 13. 1906.

able culture material with which to test their suggestions. The segregation of three additional species of western grass rusts of the type of *Puccinia rubigo-vera* is especially gratifying.

1. PUCCINIA ABSINTHII DC., on *Artemisia dracunculoides* Pursh, collected March 14, 1908, at Boulder, Colo., was sown on a plant of the same host species April 9. Another collection on the same host, collected March 24, 1908, at Spirit Lake, Iowa, by the writer, was similarly sown April 8. Both sowings gave rise to numerous pycnia first observed April 25, but doubtless appearing fully a week sooner, and were followed by abundant uredinia April 27. Owing to the early maturity of the leaves, no telia were produced in either case.

The results demonstrate that this rust has no aecial stage in its life cycle. As no pycnia in connection with the uredinia had been recorded for the species, either in America or Europe, and as aecia on various species of *Artemisia* are often collected in America, the status of the species had heretofore been most uncertain. The situation was changed, but still unsettled, by the production of aecia on *Artemisia dracunculoides* in the cultures of last year,[37] which were grown from telia on *Carex stenophylla.* The present cultures very satisfactorily complete our knowledge of the two most common rusts on *Artemisia.*

2. PUCCINIA on *Carex comosa* Boott, collected at Lewes, Del., Nov. 15, 1907, by Mr. H. S. Jackson (no. 1858), was sown April 25, on *Iva frutescens, Urtica gracilis,* and *Smilax hispida,* with no infection, the *Smilax* leaves, however, having died before infection could have shown. Another sowing was made May 22 on the same hosts, and also on *Myrica cerifera* and *Ambrosia trifida.* There was no infection except in the case of *Smilax,* on which pycnia were noticed June 8, although they might have appeared sooner, and were followed by aecia June 24.

The clues to this connection of telia and aecia were slight. In reference to his collection Mr. Jackson wrote that "in the locality from which the specimen came was a vine of *Smilax rotundifolia* with aecia," but he laid little stress on this association, and did not even retain a specimen of the *Smilax* rust. Upon visiting the locality again in April no *Smilax* aecia could be found, doubt-

[37] See Jour. Myc. 14: 21. 1908.

less because too early in the season. Some additional probability of the connection, however, was secured from a microscopic examination. The urediniospores of the *Carex* rust proved to be remarkably large, while the aeciospores on *Smilax,* belonging to *Aecidium macrosporum* Peck, are also unusually large, as the name indicates. But on the other hand the western *Smilax* aecia belong to a grass rust, and most *Carex* rusts have aecia on composite hosts. It is, therefore, more than usually gratifying to complete the life cycle of this heretofore undetected *Carex* rust. It is probably a more widely distributed species than shown by the range of the present known aecial collections, all of which are eastern, except one from Kansas.

Puccinia macrospora (Peck) nom. nov.

(*Aecidium macrosporum* Peck, 23rd Rep. N. Y. St. Mus. 61. 1873.)

O. Pycnia epiphyllous, few in groups on slightly discolored spots, not conspicuous, subepidermal, in vertical section flattened-globoid, 128–160μ in diameter by 80–100μ high.

I. Aecia hypophyllous, chiefly in annular groups 1.5–5 mm. across, rather short, 0.1–0.2 mm. in diameter; peridial cells linear-rhomboidal, 32–42μ long, outer wall thin, smooth, inner wall somewhat thicker, moderately verrucose; aeciospores globoid, very large, 32–42 by 37–51μ, wall colorless, medium thick, 1.5–2.5μ, thicker above, 5–10μ, rather coarsely verrucose.

On *Smilax hispida* Muhl., Long Branch, N. J., July, 1870, *G. W. Clinton;* Manhattan, Kans., June 25, 1886, *W. A. Kellerman; S. rotundifolia* L., Riverhead, Suffolk Co., N. Y., 1869, *Charles H. Peck* (type); Brown's Mills, N. J., June 26, 1889, *B. Halsted;* Seaford, Del., July 9, 1907, *H. S. Jackson;* Lewes, Del., June 6, 1908, *M. T. Cook & H. S. Jackson.*

II. Uredinia amphigenous, scattered or in longitudinal series, oblong, 0.5–1 mm. long, tardily dehiscent; urediniospores obovate or narrowly ellipsoid, rather irregular, very large, 26–37 by 40–60μ, often narrowed below to a thickened hilum; wall golden yellow, evenly thick, 2.5–3.5μ, echinulate with prominent points 3–4μ apart; pores obscure, 2 or sometimes 3, equatorial.

III. Telia chiefly hypophyllous, scattered or in longitudinal series, oblong or linear, 0.5–1.5μ long, finally naked, pulvinate, chocolate-brown, ruptured epidermis noticeable; teliospores clavate, 16–23 by 61–67μ, usually rounded or obtuse above, narrowed below, usually slightly constricted at the septum; wall pale

cinnamon-brown, paler below, medium thin, 1.5–2.5μ, much thicker at apex, 9–16μ; pedicel nearly colorless, one half to once length of spore.

On *Carex comosa* Boott, Lewes, Del., Nov. 15, 1907, *H. S. Jackson 1858.*

3. PUCCINIA on *Carex pratensis* Drej. An observation by Mr. E. Bethel at Tolland, Colo., July 25, 1907, when aecia on *Agoseris* were found in very close proximity to rusted *Carex pratensis,* led to a collection of telial material from the same spot in October following, and a successful culture. The teliospores were sown May 13, on a plant of *Agoseris glauca,* raised from seed previously sent by Mr. Bethel, and pycnia began to show May 19 in the greatest abundance. The infection was so heavy that the plant was killed before aecia were formed.

A study of all available data regarding this species has led to the conclusion that a very large part of all collections of aecia on the various species of *Agoseris* belong to this species, and not as sometimes assumed to *Puccinia Troximontis* Peck, which is common on the same hosts, but probably has no aecial stage. A description of the species is appended, but no attempt will be made at this time to cite the numerous known localities or to map out the range, which doubtless embraces much of the western mountainous region.

Puccinia patruelis sp. nov.

O. Pycnia amphigenous, rather few, in groups 0.5–1 mm. across, punctiform, inconspicuous, honey-yellow becoming brownish, subepidermal, in vertical section globoid, 96–125μ in diameter by 80–100μ high; ostiolar filaments 30–55μ long.

I. Aecia amphigenous, numerous in crowded groups 1–4 mm. across, often surrounding groups of pycnia; peridium colorless, rather short, margin finely lacerate; peridial cells rhomboidal, 18–25μ long, outer wall rather thick, 3–4μ, striate, smooth, inner quite thin, finely verrucose; aeciospores mostly globoid, 13–16 by 16–21μ; wall colorless, thin, 1μ, very finely verrucose, appearing smooth when wet.

On *Agoseris glauca* (Pursh) Greene (*Troximon glaucum* Pursh), Tolland, Colo., July 25, 1907, *E. Bethel.*

II. Uredinia chiefly hypophyllous, scattered, oblong or oval, 0.4–0.6 mm. long, rather tardily naked, cinnamon-brown; urediniospores ellipsoid or obovate-ellipsoid, 13–19 by 19–26μ; wall golden-brown, moderately echinulate, pores 2, lateral and opposite, slightly superequatorial.

III. Telia hypophyllous, scattered, numerous, oval or oblong, 0.3–0.8 mm. long, early naked, dark blackish-brown, conspicuous, ruptured epidermis noticeable; teliospores broadly clavate or spatulate, 15–23 by 32–63μ, apex rounded or obtuse, base usually narrowed, slightly constricted at the septum; wall dark chestnut-brown, paler below, moderately thin, 1.5–2μ, thicker at apex 7–13μ; pedicel slightly colored next the spore, somewhat shorter than the spore.

On *Carex pratensis* Drej., Tolland, Colo., July 25 and Oct. 19, 1907, *E. Bethel* (type).

4. PUCCINIA CINEREA Arth., on *Puccinellia airoides* (Nutt.) Wats. & Coult., collected at Arvada, Colo., by Mr. E. Bethel, was sown April 22 on *Oxygraphis Cymbalaria* (Pursh) Prantl (*Ranunculus Cymbalaria* Pursh), giving rise to pycnia April 30, and aecia May 4. A duplicate sowing was made May 7, and pycnia followed May 14, with aecia May 19. In each case the sori were produced in abundance .

The clue for this combination was obtained by Rev. J. M. Bates, who had found the same species of rust on *Poa* growing in proximity to rusted *Oxygraphis* in a number of places in Nebraska under conditions which seemed to make their genetic connection almost certain.[38] Unfortunately the culture material sent by him both this year and previously failed to germinate. The plants of *Oxygraphis* used for the cultures were supplied by him. The Colorado material was received unnamed, and from its general appearance was supposed to be on some species of *Poa,* until after the work was completed when the determination was made by Mrs. Agnes Chase of the agrostological division of the National Herbarium.

5. PUCCINIA on *Koeleria cristata.* A number of collections of this rust were sent by Mr. E .Bethel, who made the suggestion several times that it was probably connected with aecia on *Mahonia,* a suggestion that seemed to us unimportant, as the aecia on *Mahonia* in Europe are known to belong to *Puccinia poculiformis,* a cosmopolitan rust wholly unlike the one on *Koeleria.* As a collection made by Mr. Bethel April 25, 1908, at Plainview, Colo., showed germination, and as he had written that "the rust on *Koeleria* undoubtedly belongs to the aecia on *Mahonia,* for I have

[38] See Bull. Torrey Club 34: 584. 1907.

found hundreds of cases to substantiate it—I wish you would try it," a sowing was accordingly made April 30 on *Mahonia Aquifolium.* Abundance of pycnia appeared May 14, and aecia May 24. Another sowing was made June 2 on *Berberis vulgaris,* but gave no infection.

Upon examination of the available collections of aecia on *Mahonia,* which had not been given careful study before, it was discovered that they differed in a characteristic way from those on *Berberis.* They are smaller, do not produce a thickening of the leaf, and cause a rounded area of the leaf on which each group is seated to die early, turning brown and dry. From our inquiry it seems probable that no aecia on *Mahonia* belonging to *Puccinia poculiformis* have yet been found in America, although they have been so cited, but that they all should go under the present species, a description of which follows.

Puccinia Koeleriae sp. nov.

O. Pycnia chiefly epiphyllous, numerous, rather loosely arranged in groups 0.5–2 mm. across, on discolored spots, punctiform, not conspicuous, subepidermal, honey-yellow becoming blackish, in vertical section lenticular, 80–100μ in diameter by 45–65μ high.

I. Aecia hypophyllous, numerous, usually crowded in groups 1–3 mm. or more across, on discolored spots 1–7 mm. across, which finally die and turn blackish-brown, short cylindrical, 0.4–0.7 mm. high by 0.1–0.2 mm. in diameter; peridium colorless, cells rhomboidal in radial section, outer wall rather thick, 5–7μ, transversely striate, inner wall medium thin, 1–3μ, verrucose; aeciospores globoid, 13–20 by 18–26μ, wall colorless, rather thin, 1–1.5μ, evenly and finely verrucose.

On *Mahonia Aquifolium* (Pursh) Nutt. (*Berberis Aquifolium* Pursh, *B. repens* Lindl.), Ouray, Colo., July 26, 1897, *C. L. Shear,* July 2, 1907, *E. Bethel;* Victor, Idaho, July 10, 1901, *E. D. Merrill & E. N. Wilcox;* Wild Horse Island, Mont., Aug. 13, 1908, *M. E. Jones 7718;* Yellow Bay, Mont., Aug. 10, 1908, *M. E. Jones 7723.*

II. Uredinia amphigenous, in groups on discolored spots, oblong or linear, 0.1–0.2 mm. wide by 0.5–1.5 mm. long, soon naked, pulverulent, cinnamon-brown, ruptured epidermis conspicuous; paraphyses numerous, capitate or clavate-capitate, 10–16 by 42–65μ; urediniospores broadly ellipsoid, 19–26 by 23–34μ; wall cinnamon-brown, medium thick, 2–2.5μ, rather closely echinulate-verrucose; pores 4–6, scattered.

III. Telia hypophyllous, scattered, oblong or linear, about 0.1

mm. wide by 0.5–1.5 mm. long, sometimes confluent, long covered by the epidermis, grayish-black; teliospores clavate or oblong-clavate, 15–21 by 45–55μ, obtuse or truncate above, narrowed below; wall chestnut-brown, paler beneath, thin, about 1μ, thicker at apex, 3–5μ, smooth; pedicel short, slightly colored.

On *Koeleria cristata* (L.) Pers., Ouray, Colo., Aug. 23, 1907, *E. Bethel* (type); Boulder, July 31, 1905, Plainview, Aug. 5, 1905, and April 25, 1908, Marshall, June 24, 1905, Golden, July 27, 1908, all in Colo., *E. Bethel.*

6. PUCCINIA on *Bromus.* A subepidermal rust on various species of *Bromus* is common in the western mountains. Collections made by Prof. E. W. D. Holway, Sept. 4 and 7, 1907, on *B. Pumpellianus* Scribn., at Banff, Alb., were found close to *Thalictrum* bearing aecia, and believed by him to be connected, but the teliospores could not be brought to germination. A collection on *B. Porteri* (Coult.) Nash, made by Mr. F. D. Kern, Sept. 2, 1908, at Ouray, Colo., with much more definite and certain field clues, being intermixed with *Thalictrum sparsiflorum* bearing aecia, was found more tractable and was sown April 30, on *Thalictrum dioicum,* giving rise to pycnia May 9, and aecia May 30, both in abundance.

It has long been recognized that the aecia on *Thalictrum* in America belong to a number of species. No cultures, however, have been made heretofore, and only the form associated with *Tranzschelia punctata* (*Puccinia Pruni-spinosae*), common in the eastern part of the country, has been definitely placed. In Europe cultures have shown aecial forms on *Thalictrum* to belong to telia on *Agrostis, Poa, Triticum, Elymus* and *Polygonum.* Whether any of these occur in America, remains to be determined, although the last two are to be expected. The species in hand appears to be unrecorded, and a description is therefore appended. It is closely related, both morphologically and in its hosts, with *P. tomipara* Trel., which ranges throughout the central and eastern states with its aecia on *Clematis* and telia on *Bromus.* The question of their exact relationship must be left to future investigation.

Puccinia alternans sp. nov.

O. Pycnia epiphyllous, crowded in groups 0.5–4 mm. across, not conspicuous, subepidermal, in vertical section globoid, 60–96μ in diameter, 50–80μ high.

I. Aecia chiefly hypophyllous, in annular or often crowded groups 1.5–5 mm. across, cylindrical, 0.4–0.8 mm. high; peridium colorless, margin slightly recurved, finely lacerate, cells rhombic in longitudinal section, 21–29μ long, walls transversely striate, outer thick, 9–12μ, inner somewhat thinner, 5–7μ, finely verrucose; aeciospores globoid or broadly ellipsoid, 15–20 by 17–24μ, wall colorless, thin, 1–1.5μ, finely and evenly verrucose.

On *Thalictrum Fendleri* Engelm., Gunnison Co., Colo., Sept. 2, 1899, *E. Bartholomew;* Salt Lake Co., Utah, July 12, 1904, *A. O. Garrett* (Sydow, Ured. *1935;* Vestergren, Micr. rar. sel. *1002;* and Garrett, Fungi Utah. *76*); *T. occidentale* A. Gray, Victor, Idaho, July 11, 1901, *E. D. Merrill & E. N. Wilcox 1256;* Banff, Alberta, July 24, 1901, and July 6, 1907, *E. W. D. Holway; T. sparsiflorum* Turcz., Ouray, Colo., Sept. 2, 1907, *F. D. Kern;* Minnehaha, Colo., Aug. 13, 1906, *F. E. Clements; T. venulosum* Trel., Spicer, Routt Co., Colo., July, 1903, *L. N. Goodding;* Macdougal Park, Mont., July 31, 1908, *M. E. Jones.*

II. Uredinia amphigenous, scattered, oblong or linear-oblong, 0.2–0.8 mm. long, rather early naked, somewhat pulverulent, cinnamon-brown, ruptured epidermis conspicuous; urediniospores very broadly ellipsoid or slightly obovate-ellipsoid, 19–25 by 23–29μ; wall light cinnamon-brown, moderately thick, 2–2.5μ, finely echinulate; pores about 6, scattered.

III. Telia amphigenous, scattered, oblong or linear-oblong, 0.4–1 mm. long by 0.2–0.4 mm. wide, long covered by the epidermis, dark blackish-brown; teliospores clavate or clavate-oblong, 13–19 by 31–61μ, usually truncate or obtuse above, narrowed below, slightly or not constricted at the septum; wall chestnut-brown, paler below, rather thin, 1–1.5μ, thicker at apex, 3–5μ, smooth; pedicel somewhat colored, very short.

On *Bromus Porteri* (Coult.) Nash, Ouray, Colo., Sept. 2, 1907, *F. D. Kern* (type); Parley's Canyon, Utah, Aug. 18, 1908, *A. O. Garrett 1137; B. Pumpellianus* Scribn., Banff, Alberta, Sept. 4 and 7, 1907, *E. W. D. Holway; B. Richardsoni* Link, Ouray, Colo., Aug. 23, 1907, *E. Bethel.*

7. PUCCINIA on *Agropyron.* Two collections of rusted *Agropyron biflorum,* collected Sept. 2, 1907, at Lake Louise, in the Canadian Selkirks, were sent by Prof. E. W. D. Holway, with the suggestion that one of them be sown on *Thalictrum* and the other on *Aquilegia.* One collection failed to germinate, the other was sown April 18 on *Aquilegia canadensis* and *Thalictrum dioicum,* with infection only on the first, the leaves of which soon began to show hypertrophy of the tissues, and in six to seven days small yellow,

translucent spots above, followed on May 8 by aecia beneath. No pycnia were formed, as sections and microscopic examination fully proved. All American collections of aecia on *Aquilegia* in the herbarium were found to have either no pycnia associated with the groups of aecia, or more rarely only a few pycnia, a condition not before noted in heteroecious rusts of grasses and sedges.

This rust is undoubtedly quite well distributed in the western mountains, and embraces a large part of all aecia yet found in America on *Aquilegia.* It is apparently distinct from *Puccinia Agrostidis* Plowr., a European species with aecia on *Aquilegia,* and is, therefore, described as new, although there is much morphological similarity between the two.

Puccinia obliterata sp. nov.

O. Pycnia few, frequently obsolete, epiphyllous, gregarious, inconspicuous, honey-yellow, in vertical section globoid, 80–107μ in diameter; ostiolar filaments 40–75μ long.

I. Aecia chiefly hypophyllous, thickly crowded in groups 1–5 mm. across, on slightly larger discolored spots, rather short; peridium colorless, margin somewhat erose, cells rhomboidal in longitudinal section, 16–24μ in length; aeciospores globoid, or often somewhat angular, 15–19 by 18–25μ, wall colorless, thin, about 1μ, very minutely verrucose, appearing nearly smooth when wet.

On *Aquilegia caerulea* James, Buffalo Pass, Park Range, Colo., Aug. 13, 1898, *C. L. Shear & E. A. Bessey* (Ellis & Ev., Fungi Columb. *1474*); Trapper's Lake, Colo., Aug. 14, 1894, *Prof. C. S. Crandall 100;* Beulah, N. Mex., June 29, 1909, *Mrs. W. P. Cockerell;* North Vermilion Creek, Sweetwater Co., Wyo., July 17, 1897, *A. Nelson; A. elegantula* Greene, Ouray, Colo., July 12, 1907, *F. E. & E. S. Clements* (Crypt. Form. Colorad. *592*); *A. flavescens* Wats., Banff, Alb., July 25, 1901, Laggan, Alb., July 21, 1907, *E. W. D. Holway; A. formosa* Fisch., Skamania Co., Wash., Aug. 12, 1886, *W. N. Suksdorf; A. truncata* Fisch. & Mey., Jackson Co., Oreg., July 9, 1903, *E. B. Copeland* (Sydow, Ured. *1767*).

II. Uredinia chiefly hypophyllous, scattered, linear, small, soon naked, pulverulent, cinnamon-brown, ruptured epidermis noticeable; urediniospores globoid or broadly ellipsoid, 16–23 by 19–29μ; wall light cinnamon-brown, medium thin, 1.5–2.5μ, finely echinulate-verrucose, pores 6–8, scattered.

III. Telia chiefly epiphyllous, scattered, often crowded and con-

fluent, oblong or linear, 0.1–0.3 mm. wide by 0.5–2 mm. long, tardily naked, blackish; teliospores clavate or clavate-oblong, 13–19 by 29–51μ, obtuse or somewhat rounded above, narrowed below, very slightly or not constricted at the septum; wall dark chestnut-brown, paler below, thin, 1–1.5μ, thicker at apex, 3–5μ, smooth; pedicel colored, short.

On *Agropyron biflorum* R. & S., Lake Louise, Laggan, Alb., Sept. 2, 1907, *E. W. D. Holway* (type); *A. caninum* (L.) Beauv., Laggan, Alb., Sept. 2, 1907, *E. W. D. Holway.*

8. PUCCINIA MUHLENBERGIAE Arth. & Holw. collected by Mr. E. Bartholomew, March 23, 1908, at Stockton, Kans., on *Muhlenbergia glomerata* Trin., was sown at different dates on ten different species of host plants, including *Hibiscus militaris* Cav., with no infection. Another collection with same data, but on *M. mexicana* (L.) Trin., was sown April 22 on *Dalea laxiflora* with no infection, again May 15 on same host, and on *Ceanothus americanus* and *Xanthoxylum americanum,* still with no infection. A third attempt was made by sowing June 12, on *Baptisia tinctoria, Rudbeckia laciniata* and *Callirrhoe involucrata.* Little culture work is done so late in the season as this last attempt, and it was supposed no infection had been secured, when on July 23 an abundance of aecia, accompanied by a few pycnia, were noticed on the plant of *Callirrhoe.* Although not under continuous observation, it is believed they came from the sowing.

Many attempts have been made to cultivate the rusts found on various species of *Muhlenbergia,*[39] twenty-six species of hosts having been used. The year following the reported success by Prof. W. A. Kellerman[40] in sowing rust from *Muhlenbergia mexicana,* collected in Ohio, on *Hibiscus Moscheutos,* a strong effort was made to repeat his work with material from Kansas and Nebraska, but with no definite result. Mr. E. Bartholomew more than once suggested that the material he supplied was connected with *Aecidium Napaeae* A. & H., as the results have seemingly shown.

The aecia obtained by Professor Kellerman, and those secured by the writer, are quite unlike. The former are rather large and

[39] For record of unsuccessful sowings see Bot. Gaz. 35: 11. 1903; Jour. Myc. 11: 51. 1905; and 13: 192. 1907.

[40] Jour. Myc. 9: 109, 232. 1903.

numerous, and bright orange-yellow, the latter are small, fewer and nearly or quite colorless. Upon a careful examination of the telial material used in the two successful trials, it is found that while that from Kansas is the true *Puccinia Muhlenbergiae,* that from Ohio is *P. dochmia* B. & C., or at least quite distinct from the other. Considerable more study is needed to fully clear up the relationship of the *Muhlenbergia* rusts.

9. GYMNOSPORANGIUM LIBOCEDRI (P. Henn.) Kern. For many years the only known locality for the telia of this rust has been in northern California at a place rarely visited by botanists. While Mr. F. D. Kern during January, 1908, was working upon material in the herbarium of Dr. W. G. Farlow at Harvard University, a collection of this rust was seen from Eugene, Ore., made by Dr. A. R. Sweetser, of the University of Oregon. There was also in the herbarium a collection, from the same locality and by the same person, of *Aecidium Blasdaleanum* D. & H. on *Crataegus.* This *Aecidium* has also been taken by more than one collector from the region of the *Libocedrus* rust in California. The *Crataegus* rust is stated by Dr. Dietel, in a note appended to the original description, to be "a true *Aecidium,* and does not belong to the genus *Roestelia* comprising the aecidial stages of *Gymnosporangium.*" Recent very careful study confirms Dr. Dietel's statement regarding its morphological resemblances, for in the peridial cells, the spores, and the mode of dehiscence, which provide the chief generic characters, it is wholly unlike the form genus *Roestelia.*

In order to secure culture material Dr. Sweetser was appealed to. He responded promply with telial collections on *Libocedrus decurrens,* which came through the mails in perfectly fresh condition. For his efficient aid Dr. Sweetser is entitled to much credit. A sowing was made April 1 on *Crataegus Pringlei* and *Amelanchier canadensis,* giving no infection on the *Amelanchier,* but on the *Crataegus* numerous pycnia began to show April 12, followed on April 20 by an abundance of well-formed aecia. Another sowing was made on *Crataegus* sp. April 4, resulting in such a heavy infection, the pycnia showing April 14, that the leaves were killed before there was time for aecia to form.

The aecia secured by the culture agree perfectly with *Aecidium*

Blasdaleanum, being wholly lacking in Roestelial characters. The aberrant form of the aecia is to a certain extent paralleled by the unusual form of the telia, which led Dr. P. Hennings to describe the telial stage as a *Phragmidium.*

10. GYMNOSPORANGIUM sp. nov. The series of circumstances leading to the discovery of telia that made the present cultures possible has been briefly narrated in the introductory paragraphs of this report. On April 10, 1908, a collection was made at Mammoth Cave, Ky., by Mr. F. D. Kern and the writer, on the branches of *Juniperus virginiana,* and on the following day a growing plant of the same species only six inches high with large sori on the main axis was obtained. The first collection was sown April 13 on *Porteranthus stipulatus* (*Gillenia stipulacea*), producing an abundance of pycnia April 21, but the plant did not thrive, soon dying outright. Another sowing of the same material was made April 15 on *Porteranthus* and also on *Crataegus punctata,* with no infection on the latter, but very abundant infection on the former, pycnia showing April 23, and aecia May 25. Another sowing April 16 on *Porteranthus* gave such a heavy infection, pycnia showing April 23, that the plant was soon killed. Still another sowing April 27, and one April 28, gave very abundant pycnia May 5, followed by numerous well-grown aecia that matured May 25 from the first sowing, and May 31 from the second. The small plant of *Juniperus* had been potted, and continued to thrive. Teliospores from this living plant were placed on a plant of *Porteranthus* May 11, and on May 17 an abundance of pycnia appeared, followed by numerous aecia that were mature by June 7.

The aecia from the cultures proved to be identical with those collected by Rev. Demetrio in 1884, at Perryville, Mo., and issued as No. 3323 in Rabenhorst-Winter, Fungi europaei. They are especially remarkable in the fact that they occur on a non-pomaceous host, an herbaceous perennial, although heretofore the aecia of all species of *Gymnosporangium* have been supposed to occur exclusively on the ligneous plants of the family Malaceae. With the aecia of this species going outside the Malaceae for its host, and those of the preceding species falling outside the genus *Roestelia,* two of the most marked characteristics pertaining to the first stage of the *Gymnosporangia* are shown to have exceptions.

Gymnosporangium exterum Arthur & Kern sp. nov.

O. Pycnia epiphyllous, rather few, very sparsely disposed in definite groups 3–6 mm. across, prominent, subepidermal, in vertical section flattened-globoid, 95–125μ in diameter by 65–90μ high; ostiolar filaments 48–65μ long.

I. Aecia hypophyllous, very sparsely disposed in large groups 4–10 mm. or more across, on larger discolored areas, 0.1–0.3 mm. in diameter by 0.5–0.8 mm. high; peridium soon becoming rather finely lacerate almost to base, spreading but not revolute, cells usually seen only in face view, 10–18 by 58–100μ, inner wall rugose with rather narrow ridges running downward and outward, side walls rugose, 3–5μ thick; aeciospores broadly ellipsoid or globoid, 17–21 by 21–26μ; wall very pale cinnamon-brown, medium thick, 2–2.5μ, very finely verrucose, pores evident, 8–10, scattered.

On *Porteranthus stipulatus* (Muhl.) Britton (*Gillenia stipulacea* Nutt., *Spiraea stipulata* Muhl.), Perryville, Mo., 1884, *C. H. Demetrio* (Rab.-Wint., Fungi Eur. *3323*); Mammoth Cave, Ky., June, 1870, *T. F. Allen.*

III. Telia caulicolous, from a permanent mycelium, appearing on fusiform swellings 2–6 cm. long by 0.5–1.5 cm. or more in diameter, causing a considerable roughening and exfoliation of the bark, flattened, irregular and indefinite in outline, usually anastomosing over practically the whole surface of the swelling, light chocolate-brown becoming yellowish by germination; teliospores ellipsoid, 18–23 by 32–42μ, rounded or sometimes narrowed above and below; wall light cinnamon-brown, rather thin, 1–1.5μ, usually slightly thicker at apex, pores 1 in each cell, apical; pedicel cylindrical, uniform, slender, 3–4μ in diameter, very long.

On *Juniperus virginiana* L., Mammoth Cave, Ky., April 10, 1908, *J. C. Arthur & F. D. Kern* (type).

SUMMARY

The following is a complete list of the successful cultures made during the year 1908. It is divided into two series: species that have previously been grown in cultures and reported by the writer or other investigators, and species whose culture is now reported for the first time.

A. Species Previously Reported

1. PUCCINIA KUHNIAE Schw.—Teliospores on *Kuhnia Hitchcockii* A. Nels., sown on *K. eupatorioides* L.

2. PUCCINIA PECKII (DeT.) Kellerm.—Teliospores on *Carex stipata* Muhl., sown on *Onagra biennis* (L.) Scop.

3. PUCCINIA SAMBUCI (Schw.) Arth.—Teliospores on *Carex lurida* Wahl., sown on *Sambucus canadensis* L.

4. PUCCINIA CARICIS-SOLIDAGINIS Arth.—Teliospores on *Carex sparganioides* Muhl., sown on *Solidago canadensis* L.

5. PUCCINIA ELEOCHARIDIS Arth.—Teliospores on *Eleocharis palustris* (L.) R. & S., sown on *Eupatorium perfoliatum* L.

6. PUCCINIA ANGUSTATA Peck.—Teliospores on *Scirpus cyperinus* (L.) Kunth., sown on *Lycopus communis* Bickn. and *L. americanus* Muhl.

7. PUCCINIA SUBNITENS Diet.—Teliospores on *Distichlis spicata* (L.) Greene, sown on *Chenopodium album* L., *Atriplex hastata* L. and *Sarcobatus vermiculatus* (Hook.) Torr.

8. PUCCINIA SEYMOURIANA Arth.—Teliospores on *Spartina cynosuroides* Willd., sown on *Cephalanthus occidentalis* L.

9. PUCCINIA FRAXINATA (Schw.) Arth.—Teliospores on *Spartina polystachya* Willd. and on *S. stricta* Roth, sown on *Fraxinus lanceolata* Borck.

10. PUCCINIA TOMIPARA Trel.—Teliospores on *Bromus purgans* L., sown on *Clematis virginiana* L.

11. PUCCINIA ASPERIFOLII (Pers.) Wettst.—Teliospores on *Secale cereale* L., sown on *Lycopsis arvensis* L.

12. UROMYCES SCIRPI (Cast.) Burr.—Teliospores on *Scirpus fluviatilis* (Torr.) A. Gray, sown on *Cicuta maculata* L.

13. UROMYCES HOUSTONIATUS (Schw.) Sheldon.—Aeciospores on *Houstonia caerulea* L., sown on *Sisyrinchium gramineum* Curtis.

14. GYMNOSPORANGIUM JUNIPERI-VIRGINIANAE Schw.—Teliospores on *Juniperus virginiana* L., sown on *Malus coronaria* (L.) Mill., *M. Malus* (L.) Britt. and *Crataegus punctata* Jacq.

15. GYMNOSPORANGIUM GLOBOSUM Farl.—Teliospores on *Juniperus virginiana* L., sown on *Crataegus Pringlei* Sarg.

16. GYMNOSPORANGIUM CLAVIPES C. & P.—Teliospores on *Juniperus virginiana* L., sown on *Crataegus* sp.

17. GYMNOSPORANGIUM CLAVARIAEFORME (Jacq.) DC.—Teliospores on *Juniperus Sibirica* Burgsd., sown on *Amelanchier erecta* Blanch.

18. GYMNOSPORANGIUM NELSONI Arth.—Teliospores on *Juniperus scopulorum* Sarg., sown on *Amelanchier erecta* Blanch. and *Sorbus americana* Marsh.

19. GYMNOSPORANGIUM BETHELI Kern.—Teliospores on *Juniperus scopulorum* Sarg., sown on *Crataegus* sp. and *Sorbus americana* Marsh.

20. GYMNOSPORANGIUM BOTRYAPITES (Schw.) Kern.—Teliospores on *Chamaecyparis thyoides* (L.) B.S.P., sown on *Amelanchier intermedia* Spach.

21. GYMNOSPORANGIUM CORNUTUM (Pers.) Arth.—Teliospores on *Juniperus Sibirica* Burgsd., sown on *Sorbus americana* Marsh.

22. GYMNOSPORANGIUM DAVISII Kern.—Teliospores on *Juniperus Sibirica* Burgsd., sown on *Aronia nigra* (Willd.) Britt.

23. MELAMPSORA MEDUSAE Thüm.—Teliospores on *Populus tremuloides* Michx., sown on *Larix laricina* (DuR.) Koch.

B. Species Reported Now for the First Time

1. PUCCINIA ABSINTHII DC.—Teliospores on *Artemisia dracunculoides* Pursh, sown on same host.

2. PUCCINIA MACROSPORA (Peck) Arth.—Teliospores on *Carex comosa* Boott, sown on *Smilax hispida* Muhl.

3. PUCCINIA PATRUELIS Arth.—Teliospores on *Carex pratensis* Drej., sown on *Agoseris glauca* (Pursh) Greene.

4. PUCCINIA CINEREA Arth.—Teliospores on *Puccinellia airoides* (Nutt.) Wats. & Coult., sown on *Oxygraphis Cymbalaria* (Pursh) Prantl.

5. PUCCINIA KOELERIAE Arth.—Teliospores on *Koeleria cristata* (L.) Pers., sown on *Mahonia Aquifolium* (Pursh) Nutt.

6. PUCCINIA ALTERNANS Arth.—Teliospores on *Bromus Porteri* (Coult.) Nash., sown on *Thalictrum dioicum* L.

7. PUCCINIA OBLITERATA Arth.—Teliospores on *Agropyron biflorum* R. & S., sown on *Aquilegia canadensis* L.

8. PUCCINIA MUHLENBERGIAE Arth. & Holw.—Teliospores on *Muhlenbergia glomerata* Trin., sown on *Callirrhoe involucrata* (T. & G.) A. Gray.

9. GYMNOSPORANGIUM LIBOCEDRI (P. Henn.) Kern.—Teliospores on *Libocedrus decurrens* Torr., sown on *Crataegus Pringlei* Sarg.

10. GYMNOSPORANGIUM EXTERUM Arth. & Kern.—Teliospores on *Juniperus virginiana* L., sown on *Porteranthus stipulatus* (Muhl.) Britt.

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